Name: Key

Chemistry 129.01 Spring 2017

General Chemistry

Midterm Examination:

Equations, constants and periodic table are provided.

You may use a calculator.

Show all your work!

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Bonus: _____/2

Total: _____/150

1. (20 pts.) A 1.32 g sample of impure magnesium was analyzed by allowing to react with an excess of HCl solution:

a) Balance the chemical equation for this reaction. (2 pts.)

$$\_\_\_\_ Mg_{(s)} + \underline{2}\ HCl_{(aq)} \rightarrow \_\_\_\_ MgCl_{2\,(aq)} + \_\_\_\_ H_{2\,(g)}$$

b) Determine the oxidation number of each element (in each reactant and product). Which element is reduced and which oxidized? Which are the oxidizing agent and reducing agent? (8 pts.)

Reactants		Products	
Element	Oxidation	Element	Oxidation Number
Mg	0	Mg	+2
H	+1	H	0
Cl	−1	Cl	−1

Mg: $0 \rightarrow +2$ oxidized Mg: reducing agent

H: $+1 \rightarrow 0$ reduced HCl: oxidizing agent

c) After the impure metal was treated with 100.0mL of 0.750 M HCl, 0.0125 mol HCl remained. Assuming the impurities do not react with the acid, was is the %Mg in the sample? (8 pts.)

100.0 mL $\Rightarrow$ 0.1000 L

$0.1000\ L\,(0.750M) = 0.0750\ mol\ HCl$

mol HCl (that reacted) $= 0.0750\ mol\ HCl - 0.0125\ mol\ HCl_{(excess)} = 0.0625\ mol\ HCl$

$$0.0625\ mol\ HCl\left(\frac{1\ mol\ Mg}{2\ mol\ HCl}\right)\left(\frac{24.31\ g\ Mg}{1\ mol\ Mg}\right) = 0.760\ g\ Mg$$

$$\%\ Mg = \frac{0.760\ g\ Mg}{1.32\ g} \times 100 = 57.6\ \%$$

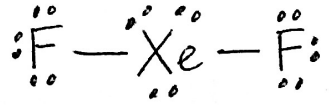
d) Assuming the volume of the solution remains constant, what is the concentration of $MgCl_2$ produced? (2 pts.)

$$0.0625\ mol\ HCl\left(\frac{1\ mol\ MgCl_2}{2\ mol\ HCl}\right) = 0.0313\ mol\ MgCl_2$$

$$M = \frac{0.0313\ mol\ MgCl_2}{0.1000\ L} = 0.313\ M\ MgCl_2$$

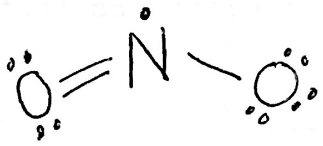
. (18 pts.) Consider the following molecules: **XeF_2, NO_2, TeF_5^-**. (i) Draw their Lewis structure, (ii) Determine the electron group and molecular geometries, (iii) Is the molecule polar or nonpolar? (iv) Hybridization of central atom

(a) XeF_2



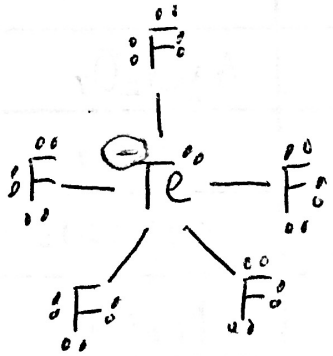
Electron Group Geometry: trigonal bipyramidal
Molecular Geometry: linear
Polar or Nonpolar?: nonpolar
Hybridization of Central Atom: sp^3d

(b) NO_2



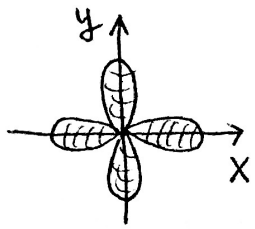
Electron Group Geometry: trigonal planar
Molecular Geometry: bent
Polar or Nonpolar?: polar
Hybridization of Central Atom: sp^2

(c) TeF_5^-

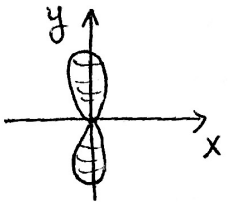


Electron Group Geometry: octahedral
Molecular Geometry: square pyramidal
Polar or Nonpolar?: polar
Hybridization of Central Atom: sp^3d^2

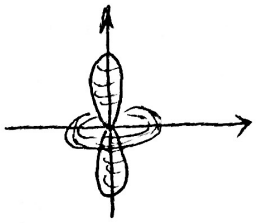
3. (i) (3 pts) Draw the following orbitals (shape and orientation):
dx^2-y^2 , p_y and dz^2 orbitals



dx^2-y^2



p_y



dz^2

(ii) (2 pts) Tell whether the following combinations of quantum numbers are allowed or not allowed.

n = 2, l = 3, m_l = -1 — not allowed

n = 3, l = 2, m_l = +2 — allowed

(iii) (4 pts) What is the maximum number of electrons that can have of the following quantum numbers?

n = 4, l = 3, m_s = -½ — 7

n = 3, l = 2 — 10

4. (6 pts.) Fill in the gaps in the following table.

Name	Formula
silver dichromate	$Ag_2Cr_2O_7$
chromium (III) chloride	$CrCl_3$
iron (II) perchlorate	$Fe(ClO_4)_2$
dinitrogen tetroxide	N_2O_4
sulfur dioxide	SO_2
sodium phosphate	Na_3PO_4

5. (2 pts) (i) Write the **full** electron configuration for **Mn**.

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$

(ii) (3pts) Arrange the following elements in order of **increasing** atomic radius: Mg, F, Rb^+, Al, Rb, S

$F < S < Al < Mg < Rb^+ < Rb$

(iii) (3 pts) Arrange the following elements in order of **increasing** ionization energy: O, Cs, B, Ga, Sr.

$Cs < Sr < Ga < B < O$

(iv) (5 pts) Arrange the following atoms in order of **increasing** electronegativity: H, Cs, N.

$Cs < H < N$

What type of bond (ionic, polar or nonpolar) would each of those atoms make with <u>another N atom</u>?

H polar

Cs ionic

N nonpolar

6. (7 pts) The energy of an orbit in the hydrogen atom is:

$$E_n = -2.18\times10^{-18} J\left(\frac{1}{n^2}\right) \qquad where\ n = 1,2,3...$$

(a) For an electron transition in the hydrogen atom from n=4 to n=1, what is the associated change in energy? Does this transition correspond to absorption or emission of energy? (4 pts.)

$n=4 \longrightarrow n=1$ Emission

$$\Delta E = -2.18\times10^{-18} J\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

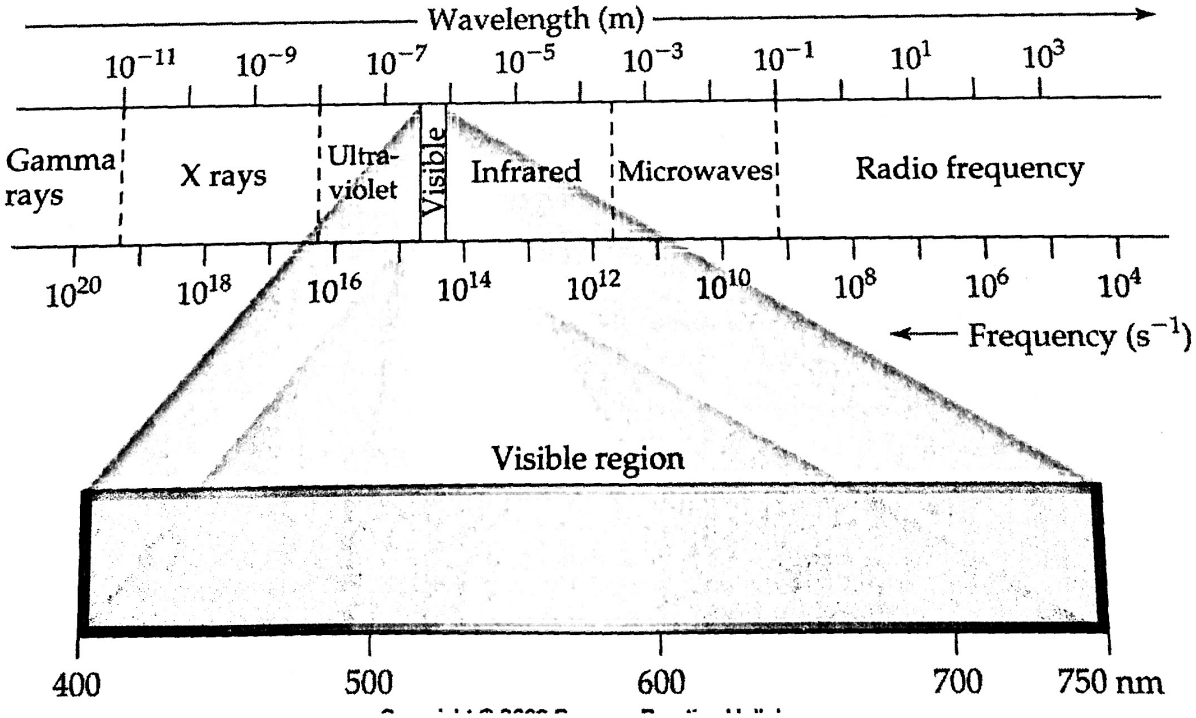
ΔE (−) ⇒ Emission

$$= -2.18\times10^{-18} J\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = -2.04\times10^{-18} J$$

(b) What is the wavelength of light this energy change corresponds to? What type of electromagnetic radiation is this? (3 pts.)

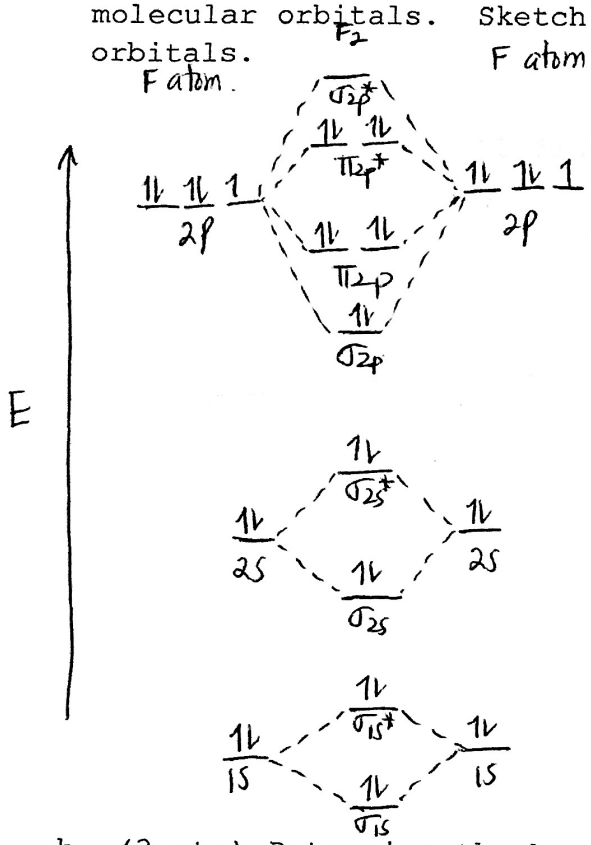
$$\lambda = \frac{(6.626\times10^{-34} J\cdot s)(3.00\times10^{8} m/s)}{2.04\times10^{-18} J} = 9.73\times10^{-8} m$$

UV light



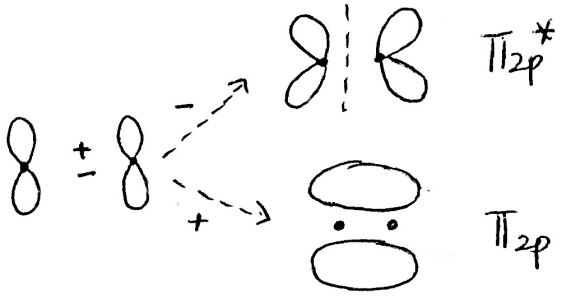
7. (17 pts.) Consider the F_2 molecule:

a. (8 pts) Draw the molecular orbital energy-level diagram for F_2 and write its electron configuration. Label all the atomic orbitals and molecular orbitals. Sketch the shape of a π_{2p} and a π_{2p}^* molecular orbitals.



Electron Configuration

↳ $\sigma_{1s}^2 \sigma_{1s}^{*2} \sigma_{2s}^2 \sigma_{2s}^{*2} \sigma_{2p}^2 \pi_{2p}^4 \pi_{2p}^{*4}$



b. (3 pts) Determine the bond order of F_2. Is F_2 paramagnetic or diamagnetic? Why?

B.O. $= \frac{1}{2}(10-8) = 1$

F_2 is diamagnetic

↳ all its electrons are paired up.

c. (6 pts.) If two electrons are removed from F_2 to form F_2^{2+}, how many unpaired electrons would F_2^{2+} have? Calculate the bond order of F_2^{2+}. Which would you expect to have a stronger bond, F_2 or F_2^{2+}? Longer bond? Why?

F_2^{2+} has two unpaired electrons

$F_2^{2+} \Rightarrow$ B.O. $= \frac{1}{2}(10-6) = 2$

F_2^{2+} has a stronger bond

F_2 has a longer bond

> The higher the bond order, the stronger the bond and the shorter the bond.

8. (10 pts) Menthol (molar mass = 156 g/mol) is a compound of C, H, and O. When 0.1005g of menthol was subjected to combustion analysis, it produced 0.2829g CO_2 and 0.1159g H_2O. Find the empirical and molecular formulas of menthol.

$$0.2829\text{ g } CO_2 \left(\frac{1\text{ mol } CO_2}{44.01\text{ g } CO_2}\right)\left(\frac{1\text{ mol C}}{1\text{ mol } CO_2}\right)\left(\frac{12.01\text{ g C}}{1\text{ mol C}}\right) = 0.07720\text{ g C}$$

$$0.1159\text{ g } H_2O \left(\frac{1\text{ mol } H_2O}{18.02\text{ g } H_2O}\right)\left(\frac{2\text{ mol H}}{1\text{ mol } H_2O}\right)\left(\frac{1.01\text{ g H}}{1\text{ mol H}}\right) = 0.01299\text{ g H}$$

$$0.1005\text{ g sample} - 0.07720\text{ g C} - 0.01299\text{ g H} = 0.01031\text{ g O}$$

$$0.07720\text{ g C}\left(\frac{1\text{ mol C}}{12.01\text{ g C}}\right) = 0.006428\text{ mol C}$$

$$0.01299\text{ g H}\left(\frac{1\text{ mol H}}{1.01\text{ g H}}\right) = 0.01286\text{ mol H}$$

$$0.01031\text{ g O}\left(\frac{1\text{ mol O}}{16.00\text{ g O}}\right) = 0.0006444\text{ mol O}$$

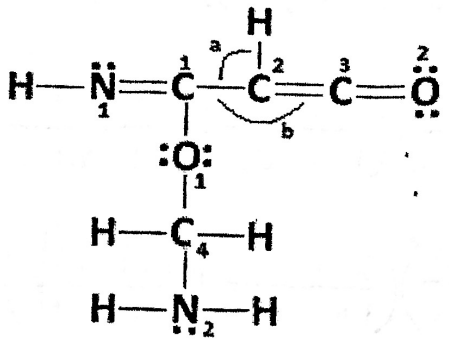
$$\frac{C_{0.006428}}{0.0006444}\frac{H_{0.01286}}{0.0006444}\frac{O_{0.0006444}}{0.0006444} \Rightarrow \underline{C_{10}H_{20}O} \Leftarrow \text{Empirical Formula}$$

156.309/mol

$$n = \frac{156\text{ g/mol}}{156.3\text{ g/mol}} \approx 1$$

Molecular Formula: $\underline{C_{10}H_{20}O}$

9. (11 pts.) (a) What are the hybridizations of the **four carbon,** the **two oxygen,** and **two nitrogen** atoms?



C_1: sp^2 O_1: sp^3 N_1: sp^2

C_2: sp^2 O_2: sp^2 N_2: sp^3

C_3: sp

C_4: sp^3

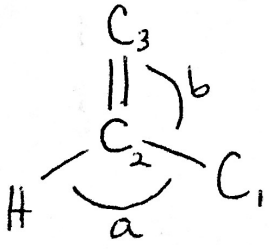
How many sigma bonds and pi bonds does the molecule have?

13 sigma bonds 3 pi bonds

(c) Which angle is smaller a or b? Explain.

Angle a is smaller than b.

Carbon #2 is trigonal planar. Trigonal Planar electron-group geometry predicts 120° angles.



Angle b is larger because electron-groups for multiple bonds exert greater repulsive force on adjacent electron domains than single bonds do.

10. (15pts) (a) When KCl dissolves in water, the main force of attraction that exists between Cl^- and H_2O is called ion-dipole.

(b) Chlorine (Cl_2) is a gas at room temperature. What is the major attractive force that exists among different Cl_2 molecules in the gas? London Dispersion Forces.

(c) Arrange the following in order of **increasing** boiling point: CH_3CH_2OH, $CH_3CH_2CH_3$, and CH_3OCH_3. Explain.

Boiling Points: −42.2°C, −24.0°C, 78.2°C
Molar Masses: 44.10 g/mol, 46.07 g/mol, 46.07 g/mol

$CH_3CH_2CH_3 < CH_3OCH_3 < CH_3CH_2OH$

↓ LDF

↓ LDF, Dipole-Dipole

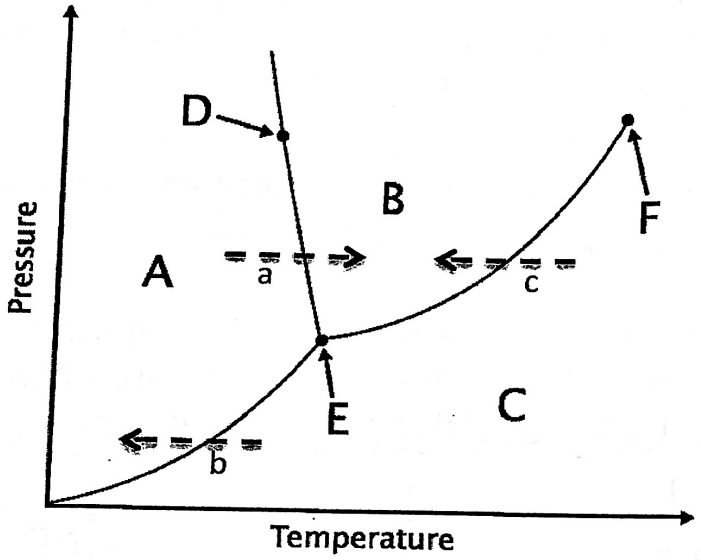
↓ LDF, Dipole-Dipole, H Bond

Stronger intermolecular forces, higher boiling point. $CH_3CH_2CH_3$ is nonpolar & only forces present are dispersion forces so it has the lowest boiling point. Both CH_3OCH_3 and CH_3CH_2OH are polar molecules so (in addition to dispersion forces) they have dipole-dipole forces present. CH_3CH_2OH can hydrogen bond and CH_3OCH_3 cannot so it has the highest boiling point.

(d) Which molecule would you expect to be more soluble in water, CCl_4 or $CHCl_3$? Why?

$CHCl_3$ is more soluble in water than CCl_4. CCl_4 is a nonpolar molecule and $CHCl_3$ is polar. $CHCl_3$ and water are both polar and have similar intermolecular attractive forces.

11. (15pts) (i) The phase diagram of a hypothetical substance is shown in the following figure. Identify the phase(s) present at points A through F.



A: Solid

B: Liquid

C: Gas

D: Solid & Liquid

E: Solid, Liquid & Gas

F: Supercritical Fluid (beyond this point)

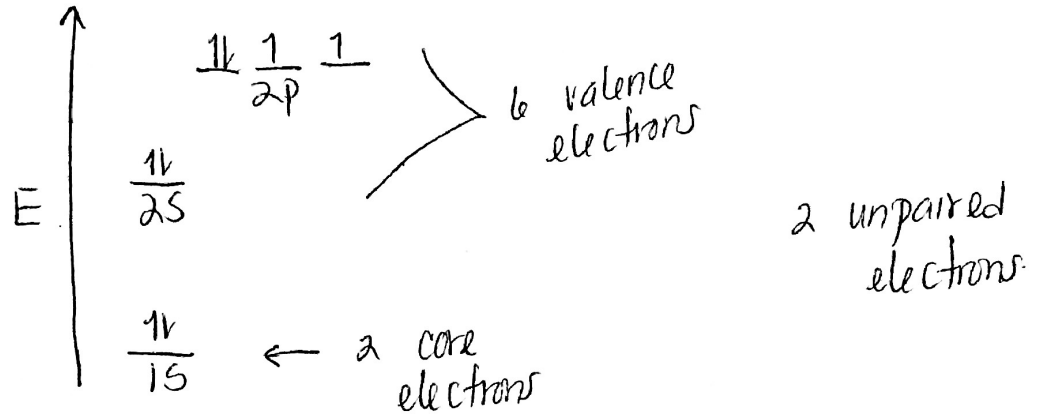
(ii) Name the phase change shown by the dashed arrows. Is the process endothermic or exothermic?

a. melting - endothermic

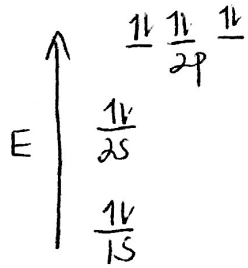
b. deposition - exothermic

c. condensation - exothermic

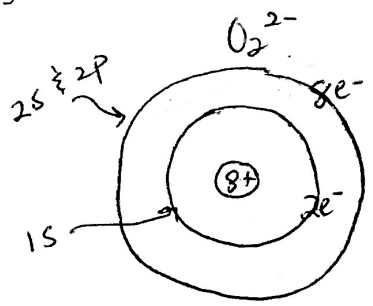
12. (i) (6 pts) Draw the **atomic orbital diagram** of **oxygen** and <u>show the number of valence electrons, core electrons and unpaired electrons</u>.



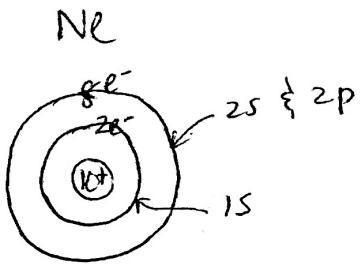
(ii) (3 pts.) The oxide ion, O^{2-}, is isoelectronic (has exactly the same number and configuration of electrons) with Ne, and yet O^{2-} is bigger than Ne. Why?



O^{2-} & Ne



$Z_{eff} = 8 - 2 = 6^+$



$Z_{eff} = 10 - 2 = 8^+$

O_2^{2-} & Ne have the same number of electrons but Ne has a larger effective nuclear charge (more protons & same number of core e^-s) so it holds the electrons more tightly.

Bonus: (2 pts)

Arrange the following in order of <u>increasing</u> length. Explain.

Cl—Cl H—H H—Cl

74pm 127pm 199pm

H-H < H-Cl < Cl-Cl

length →

As the size of the atoms increases, the bond length increase too.